CERES PATHFINDER CLOUD RETRIEVAL AND RADIATION BUDGET PRODUCTS DERIVED FROM MERGED AVHRR, HIRS/2, AND ERBE DATA

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1. INTRODUCTION

The first launch of the Clouds and the Earth's Radiant Energy System (CERES) instrument is planned for the Tropical Rainfall Measurement Mission (TRMM) platform in 1997, with future launches on the EOS-AM and EOS-PM platforms. Under the auspices of the CERES project, operational procedures are being developed and implemented to merge higher spatial resolution imager data with lower spatial resolution broadband CERES data. The anticipated cloud imagers include the Visible Infrared Scanner (VIRS, 2-km resolution) on the TRMM platform and the Moderate Resolution Imaging Spectrometer (MODIS, 0.25-km, 0.5-km, and 1-km resolution) on EOS-AM and EOS-PM platforms.

Algorithms are being developed and tested using data from the NOAA-9 Advanced Very High Resolution Radiometer (AVHRR), High-resolution Infrared Radiometer Sounder (HIRS/2), and Earth Radiation Budget Experiment (ERBE) instruments as surrogates for anticipated CERES broadband radiometric data. The convolution of the data from the AVHRR, HIRS/2, and ERBE instruments provides a unique data set with which to study ways to improve scene identification for inversion of ERBE (and in the future, CERES) broadband radiance measurements to top-of-atmosphere (TOA) fluxes.

This paper outlines the procedures to retrieve clear-sky and cloud properties from imager data, to convolve the imager-derived data with the broadband CERES/ERBE measurements, and then to calculate top-of-atmosphere fluxes. Through the EOS Pathfinder program, data products using these new procedures will be available through the NASA Langley Research Center (LaRC) Distributed Active Archive Center (http://eosdis.larc.nasa.gov).

2. DATA

The NOAA-9 AVHRR spectral data consist of channels 1 (0.65 μm), 2 (0.83 μm), 3 (3.7 μm), 4 (10.8 μm), and 5 (11.8 μm). Channel 1 and 2 radiances are converted to bidirectional reflectances. The near-infrared (NIR) and infrared (IR) radiances are calculated from the raw counts provided in the NOAA Level 1-B data stream using the nominal calibration and include nonlinearity corrections (Kidwell, 1995).

The HIRS/2 radiometric sounding unit is one of three components that make up the TOVS (TIROS Operational Vertical Sounder; TIROS is the Television and Infrared Observation Satellite) instrument package. The HIRS/2 instrument (~17.4 km resolution at nadir) receives visible and infrared radiation through a single telescope and splits the radiation into 19 narrowband infrared channels and one visible narrowband channel by means of a rotating filter wheel. Further details on the AVHRR and HIRS/2 instruments and data streams are provided in Kidwell (1995).

The NOAA-9 ERBE instrument includes a scanning and a nonscanning radiometer (Barkstrom and Smith 1986) that measures longwave (LW) radiances (5 to 50 μm) and shortwave radiances (0 to 5 μm). Only scanner data are used in the Pathfinder effort. Calibrated data from ERBE are available at the LaRC DAAC.

Several ancillary data sets are used in the Pathfinder data reduction process. The Data Assimilation Office (DAO; http://hera.gsfc.nasa.gov/dao.home_page.html) at NASA Goddard Space Flight Center provides 2^{o} by 2.5^{o} gridded temperature and humidity profiles. In addition to the gridded profiles, a variety of surface maps are used in the processing, such as a surface type map provided by the International Geosphere Biosphere Programme (IGBP), surface emittance map, and a broadband albedo map. Further surface map details are provided at http://tanalo.larc.nasa.gov:8080/surf_htmls/SARB_surf.html.

3. METHODOLOGY

The CERES cloud retrieval process is as follows. The first step involves assigning ancillary data to each imager pixel, such as viewing geometry (solar zenith, viewing zenith, relative azimuth, and scattering angles), surface elevation, surface ecosystem type, etc. Second, the imager data are analyzed to determine which pixels are obstructed between the surface and the satellite (Berendes et al. 1996; Baum et al. 1995a). Third, the radiances for the unobstructed pixels are used to update a clear-sky radiance/brightness temperature map. At the same time, a skin temperature is derived for each clear-sky pixel. Atmospheric absorption is computed using a correlated *k*-distribution technique (Kratz, 1995), which uses the gridded temperature and humidity profiles and the AVHRR 10.8-μm radiance. Fourth, the data are analyzed to determine whether clouds form a single layer or multiple layers. Currently, both the spatial coherence method (Coakley and Bretherton, 1982) and the fuzzy logic method (Baum et al. 1996) are used to infer the presence of single or multiple cloud layers in an array of imager pixels. In the fifth step, cloud heights are determined for each layer (Baum et al. 1995b). Finally, cloud microphysical and optical properties are inferred for each pixel where possible (Minnis et al. 1995). While the presence of multiple cloud layers may be inferred within an imager pixel array, cloud microphysical and optical properties are derived under the assumption that each pixel has only one cloud layer. In future versions of the CERES Pathfinder effort, we will begin to address the cloud overlap issue.

The processed imager data are convolved subsequently with the instantaneous ERBE scanner broadband measurements. The convolution (Green and Wielicki 1995) process uses a point spread function (PSF) generated from knowledge of the instrument detectors and scanning characteristics. The CERES production code formally uses a CERES PSF; however, the ERBE PSF is used for Pathfinder data processing. The ERBE field of view (FOV) is much larger (~40 km at nadir) than the CERES FOV (~10 km for TRMM, ~20 km for EOS-AM at nadir). After the convolution process, the broadband radiances are inverted to TOA fluxes (Green et al. 1995). The Pathfinder AVHRR/ERBE data set incorporates a new set of Angular Distribution Models derived from the Radiance Pairs Method (Green and Hinton 1996) for converting broadband radiance to TOA flux. The new shortwave ADM's are more accurate than the original ADM's used for the original ERBE processing. CERES-related documentation, including the most current Algorithm Theoretical Basis Documents, are available digitally at http://asd-www.larc.nasa.gov/ceres/ASDceres.html.

4. PRODUCTS

Three distinct data products are being generated as part of the CERES Pathfinder effort. The CERES Pathfinder data granule is defined to be one hour. The products currently include:

1. An imager-based pixel-level cloud/clear-sky product is generated solely from AVHRR data.
2. A convolved AVHRR/ERBE product that essentially contains the instantaneous ERBE radiances, TOA fluxes, and the convolved imager-based clear-sky and cloud properties.
3. An instantaneous gridded product merges AVHRR-based clear-sky and cloud properties with ERBE-derived top-of-atmosphere fluxes onto a 2.5^{o} equal-area grid. Additionally, cloud-top heights and effective cloud fractions are added from application of the CO_2 slicing technique to the HIRS/2 data stream. The HIRS/2 data stream is processed in parallel with the AVHRR data. The use of the HIRS/2 data serves two goals: first, to compare HIRS/2-derived cirrus cloud heights with various AVHRR retrieval schemes, and second, to gain experience in using anticipated MODIS channels for problematic regions such as nighttime cloud retrieval over poles (Francis, 1996).

Two full months of global data (June 1986 and October 1986) will be processed and the resulting data products will be available through the NASA LaRC DAAC. Detailed data structures for all three products may be found on the Pathfinder home page (under the LaRC DAAC home page http://eosdis.larc.nasa.gov). Examples will be shown that detail the algorithm improvements and various results from the data processing.

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